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CHAMBER MAPPING SYSTEM

Cross Reference to Related Applications

F1 The present application is a Continuation-In-Part of 08/387,832 filed 5/26/95 which is incorporated herein in its entirety by reference.

1. Field of the Invention

The present invention relates generally to the field of electro-physiology and more particularly to a system for creating a three dimensional geometric model or map of a cardiac chamber.

2. Background of the Invention

Knowledge of the shape of a cardiac chamber is useful in a variety of medical applications. For example, it may be desirable to display electrophysiologic data on a realistically shaped cardiac surface to facilitate diagnostic procedures or to facilitate minimally invasive surgical procedures. It has been shown that the ability to present bio-potentials on such a surface provides a powerful diagnostic tool for understanding cardiac arrhythmia. Such systems are known from U.S. Patent 5,553,611 and U.S. Patent 5,291,549. In prior systems such knowledge is used to calibrate the system so that physical dimensions displayed to a clinician match the actual dimensions of the heart. Accurate knowledge of chamber geometry throughout the cardiac cycle may provide more computationally efficient methods for nearly real time diagnostic and/or therapeutic interventions. In this sense refined knowledge of the shape of the chamber is useful even if it is not displayed to the physician.

In general it is desirable to quickly acquire chamber geometry and there is a need to develop methods that accomplish this result in a clinical setting.

Summary of the Invention

In the present invention a catheter having a "location" device is moved along the interior surface of the heart by the clinician. During this procedure the location of the catheter is monitored by a mapping system. This "tracing" process collects a relatively large set of mapping or data points. Each data and each measurement has a set of coordinates in physical space and has a time coordinate indicating where in the cardiac cycle the point was measured. It is important to note that any of several commercially available systems can be used to collect this coordinate data.

The software based computer system then builds a geometric figure in the form of a polyhedron from the data set. The convex hull methodology results in a polyhedron having triangular "panels". Conventional convex hull modeling techniques can be used to develop this initial shape. Next a resampling process occurs to "fill in" the data set in preparation for a smoothing operation. Next this convex hull shape is smoothed to represent a more physiologically realistic and computationally tractable shape for further use or display.

In use the clinician can control the "resolution" of the map by adding additional points. This map can be used in several ways. First the catheter used to

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"trace" the chamber may be used to deliver a therapy which may require the ability to return repeatedly to the same location in the chamber. Since wall location data can be quickly acquired it is possible to track wall motion as the heart beats. The ability to monitor wall motion provides an additional tool for diagnostic use by the clinician.

Brief Description of the Drawings

The embodiments of the invention shown are illustrative and various modifications may be made to the invention without departing from the scope of the invention. Throughout the figures identical reference numerals refer to equivalent structure, wherein:

Fig. 1 is a schematic diagram of a catheter system;

Fig. 2 is a schematic diagram of a collection of data points developed from the Fig. 1 catheter system;

Fig. 3 is a schematic diagram of a computed convex hull heart surface;

Fig. 4 is a schematic diagram of a resampled convex hull surface;

Fig. 5 is a smoothed computed heart surface:

Fig. 6 is a sequence of smoothed chamber shapes developed during a cardiac cycle; and,

Fig. 7 is a flowchart of method of carrying out the invention.

Detailed Description

Knowledge of cardiac geometry is useful in a variety applications. For example in the field of electrophysiology it may be desirable to display certain information on a representation of the cardiac surface to aid diagnostic decisions. It may also be helpful to display information on a representation of the cardiac surface to guide a therapeutic intervention. Apart from display, knowledge of chamber geometry may be useful to permit calculation of other variables such as stroke volume or ejection fraction.

Various techniques have been proposed to carry out measurements of catheter location. Although the various techniques differ in detail, most systems involve the generation of a non-ionizing field in the heart and the detection of a catheter element within that field. The source of the field may be exterior of the patient or may be created within the heart itself with an appropriate catheter system. However all of these techniques generate a set of points having locations in physical space. Suitable techniques are known from the incorporated reference and U.S. Patent 5,697,377 to Wittkampf.

Fig. 1 shows a schematic representation of a heart chamber 10 having a catheter 12 in contact with the cardiac surface 14. A field indicated by field arrow 16 creates a detectable signal at the distal element 18 of the catheter 12. The nature of the field dictates the sensor element 18. Electrical fields may be detected by electrodes, while magnetic fields may be detected by magnetic sensors.

In general the physician can manipulate the catheter 12 within the heart chamber tracing out a set of points shown by representative point 20 illustrated as a cross. The clinician may move the catheter 12 at random to develop this set of points. No pattern is implied by the distribution of points and the physician may

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select more or fewer locations of interest. The physical location of each measurement point in space is computed and collected by the computer system generally designated 22. At the end of the collection process each member of the set of data points has associated T,X,Y,Z values corresponding to the instant of data collection and the location of the data point in physical space. The data collection process is set forth in a table associated with the computer 22. For example the rows of data labeled 30 32 and 34 represent individual data points.

Fig. 2 is a graphical representation of the results of sequential measurements made in the heart. This figure is intended to show a three dimensional cloud of data points representing the tabular data of Fig. 1. For purposes of this illustration all the data points for all of the discrete measurement periods are displayed together, with representative data points 30, 32 and 34 identified in the figure.

Fig. 3 is a convex hull shape computed for the cloud of points represented in Fig. 2. This surface represents connections between the most exterior points in the data set. Usually the hull is composed of triangular panels. Convex hull algorithms are well known and publicly available software packages are available to perform this calculation, such as QHULL. See for example "The Quickhull Algorithm for Convex Hulls" by C. Bradford Barberet al. as well as the Web site at http://www.geom.umn.edu/software/qhull/.

Fig. 4 shows the resampling process carried out on a regular grid to increase the number of points for further computation. The resampling process interpolates between vertices on the exterior of the polygon. In essence intermediate points are defined within each facet of the hull or polyhedron as represented by data point 38. Although the resampling process creates "fictitious" interpolated points these points are useful in the smoothing operation shown in Fig. 5.

Fig. 5 shows a smoothed shape 39 which represents a more realistic contour than the polyhedron. This surface is computed by fitting smooth curves to the enlarged or enhanced data set generated by the resampling process. Conventional smoothing algorithms are used corresponding to a least squares fit. This process yields a mathematically differentiable surface.

Fig. 6 shows the process taken at several different times in the cardiac cycle. For example chamber 40 was reconstructed at time 42, while chamber 44 was reconstructed at time 46. In a similar fashion chamber 48 is reconstructed at time 50. These times correspond to various stages of the heartbeat represented by the QRS complex 52. By tracking wall position as the heart contracts the clinician can extract diagnostic information concerning relative wall position, motion, and acceleration. Although there are numerous ways to use the sequential data, one useful technique is to construct a normal from the surface and to note the point at which it intersects a superimposed hull of greater volume. The distance between the two surfaces is calculated along the direction of the normal and this distance measurement is used to compute velocity and acceleration for the wall at that location.

Fig. 7 shows a flowchart showing an illustrative sequence fro carrying out the method of the invention. In process 60 the various data points associated with multiple endocardial locations are collected. Each point in this set has coordinates in space. In general several dozen points are collected. A larger data set results in a

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more complex representation of the heart; however, it is computationally more expensive.

In process 62 an algorithm is used to compute the convex hull shape. This shape estimates the boundary of the interior of the heart from the set of points. In process 64 the convex hull is resampled on a regular grid of points in physical space. By resampling the computed hull shape on the regular grid, a larger set of points is generated. Most significantly this enlarged set of points ensures that computational points are available along the length of each edge of the hull. In process 66 an algorithm is used for smoothing the convex hull shape. This process forms a mathematically differentiable shape approximating the physiologic shape of the heart chamber. Any of a number of interpolation processes can be adopted to implement this portion of the process. The final process 68 causes the model to exit to a display routine or other process where the computed shape is used for further analysis.

Although a representative illustration of the methodology is given various modifications can be made without departing from the scope of the invention.